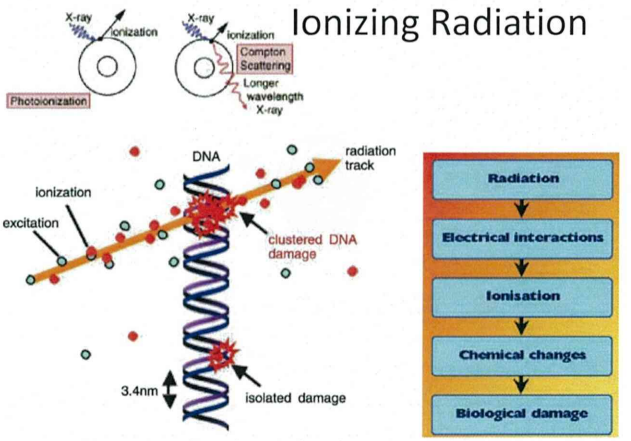
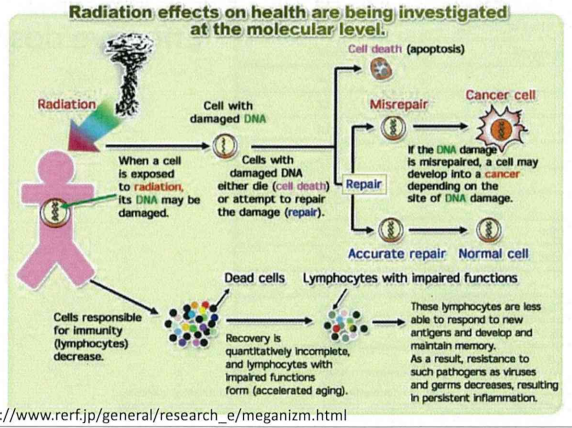
Biological Effects of Radiation

Ionizing Radiation



olisfukyu.tokai-sc.jaea.go.jp/fukyu/mirai-en/2008/6_5.html

Effects of radiation on cells

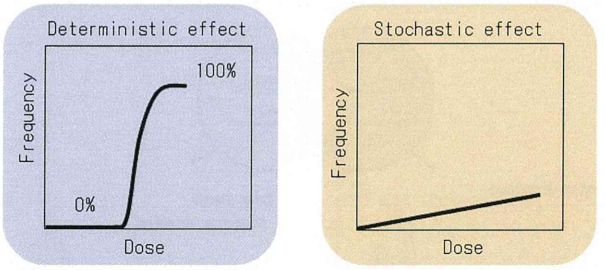


http://www.rerf.jp/general/research_e/meganizm.html

Biological Effects

- High Doses (Acute)
- Low Doses (Chronic)

Deterministic vs. Stochastic effects

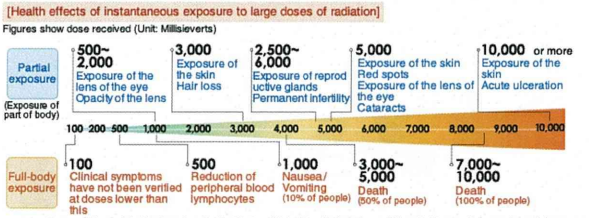


Deterministic effects are characterized by:
A threshold dose below which no effect is seen
Worsening of the effect as dose increases over the threshold
Always occurring once the threshold dose is reached
Different effects, tissues and people have different threshold doses for deterministic effects
All early effects, and most normal tissue late effects are deterministic.

Stochastic effects account for the remaining late effects:
They have no threshold dose
They increase in likelihood as dose increase
Their severity is not dose related
There is no dose above which stochastic effects are certain to occur
Stochastic effects include radiation carcinogenesis and hereditary effects

http://www.nirs.go.jp/db/anzendb/NORMDB/ENG/1_yougosyuu.php

If cells are exposed to high levels of radiation all at once, they cannot repair themselves



Source: Formulated using data in Radiation Q&A, The Federation of Electric Power Companies of Japan

- When exposed to high levels of radiation all at once, damaged cells are unable to sufficiently repair themselves, and this has effects on health.
- Epidemiological surveys and other studies have shown that exposure to high levels of radiation all at once has the health effects shown in the figure above. Exposure of the entire body has greater health effects than exposure of part of the body at the same level of radiation.

High Dose Effects

Dose (Gy)	Effect Observed
0.15-0.2	Blood count changes in a group of people
0.5	Blood count changes in an individual
1	Vomiting (threshold)
1.5	Death (threshold)
3.2 – 3.6	LD 50/60 with minimal care
4.8 – 5.4	LD 50/60 with supportive medical care
11	LD 50/60 with intensive medical care

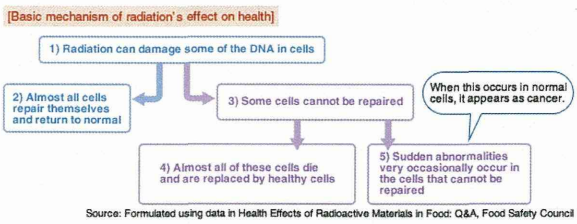
Acute Radiation Sickness

Symptoms and treatment strategy		Mild (1-2Gy)	Moderate (2-4Gy)	Severe (4-6Gy)	Very severe (6-8Gy)	Lethal (a) (>8Gy)
Vomiting	Onset Incidence	After 2 hrs 10-50%	After 1-2 hrs 70-90%	Within 1hr 100%	Within 30 min 100%	Within 10 min 100%
Diarrhea	Onset Incidence	None - -	None - -	Mild 3-8hrs <10%	Heavy 1-3hrs >10%	Heavy within minutes-1hr almost 100%
Headache	Onset Incidence	Slight - -	Mild - -	Moderate 4-24hrs 50%	Severe 3-4hrs 80%	Severe 1-2hrs 80-90%
Consciousness	Onset Incidence	Alert - -	Alert - -	Alert - -	Possibility of impairment - -	Unconsciousness by order of seconds or minutes Seconds-minutes 100% (>50Gy)
Body Temperature	Onset Incidence	Normal - -	Increased 1-3 hrs 10-80%	Fever 1-2 hrs 80-100%	High fever < 1 hrs 100%	High fever < 1 hrs 100%
Treatment Strategy		Outpatient observation	Observation at general hospital, treatment at specialized hospital if required	Treatment at specialized hospital	Treatment at specialized hospital	Palliative treatment (a) (advanced medical care including stem cell transplantation)

Key Symptoms of ARS

- ❖ Nausea
- ❖ Vomiting
- ❖ Anorexia
- ❖ Reduced number of white blood cells (lymphocytes, granulocytes)
- ❖ Reduced number of platelets
- ❖ Itching or altered sensation in the skin
- ❖ Swelling and Edema
- ❖ Diarrhea
- ❖ Fatigue

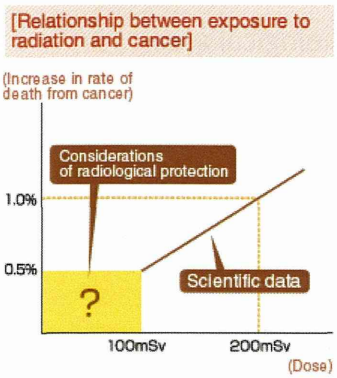
Even when exposed to radiation, the human body is able to repair itself



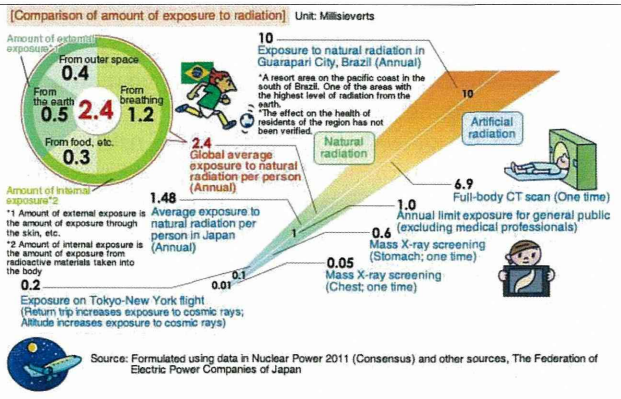
Source: Formulated using data in Health Effects of Radioactive Materials in Food: Q&A, Food Safety Council

- Exposure to radiation damages the DNA in the chromosomes, but the human body is able to repair itself, and this damage can be almost entirely repaired if the level of radiation is not too high. And even at the same level of exposure, the effect of radiation on the body is lower if the exposure occurs over several times or over a long period.

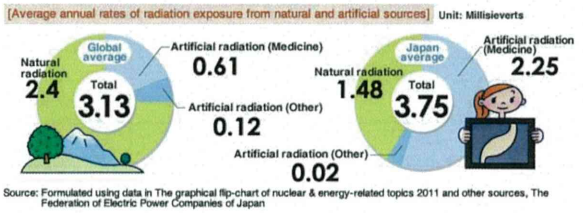
Exposure to radiation and cancer



- According to epidemiological surveys, the risk of death from cancer increases as the dose increases for exposure to doses of radiation in excess of 100 millisieverts. The International Commission on Radiological Protection (ICRP)* also estimates that the lifetime risk of death from cancer increases by approximately 0.5% with exposure to 100 millisieverts.
- However, epidemiological surveys and other studies have not verified any increase in cancer risk at doses of 100 millisieverts or less.

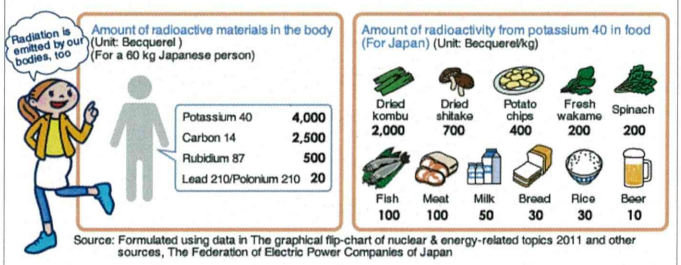


Living on the earth, humans have been exposed to radiation since ancient times. We may not be able to see it like sunlight, but radiation streams constantly onto the earth from outer space. The earth itself contains radioactive materials such as uranium and potassium, and emits radiation. As a global average, every person is exposed to approximately 2.4 millisieverts per year as a result of this radiation occurring in the natural world (natural radiation). However, the amount of natural radiation varies from region to region, depending on factors such as the presence of rocks and soil containing significant amounts of radioactive materials.



Artificial radiation:
Artificial radiation is familiar to us from its use in medicine, and people in a country like Japan, in which medicine is advanced, are exposed to a greater amount of artificial radiation than the world average.
Whether natural or artificial, the types and properties of radiation do not change, and if the figure expressed in sieverts is the same, there is no difference in their effect on the human body.

We also ingest radiation with our food



Source: Formulated using data in The graphical flip-chart of nuclear & energy-related topics 2011 and other sources, The Federation of Electric Power Companies of Japan

[Relative risk of developing cancer from radiation and lifestyle factors]

Factor	Risk of cancer
Exposure to 1,000-2,000 millisieverts of radiation	1.8X
Smoking / Drinking (0.5 liters of alcohol or more per day)	1.6X
Being underweight	1.29X
Obesity	1.22X
Exposure to 200-500 millisieverts of radiation	1.19X
Insufficient exercise	1.15-1.19X
Excessive consumption of salt	1.11-1.15X
Exposure to 100-200 millisieverts of radiation	1.08X
Insufficient consumption of vegetables	1.06X

- According to follow-up studies of individuals in Hiroshima and Nagasaki Prefectures who were exposed to the atomic bomb blasts and research on lifestyle-related diseases, exposure to 100-200 millisieverts of radiation increases the normal cancer risk by 1.08 times, but the risk associated with lifestyle factors such as not getting enough exercise and consuming too much salt is higher.

Estimated Days of Life Expectancy Lost From Various Risk Factors

Industry Type or Activity	Estimated Days of Life Expectancy Lost
Smoking 20 cigarettes a day	2370 (6.5 years)
Overweight by 20%	985 (2.7 years)
Mining and Quarrying	328
Construction	302
Agriculture	277
Government	55
Manufacturing	43
Radiation - 340 mrem/yr for 30 years	49
Radiation - 100 mrem/yr for 70 years	34

By http://www.jlab.org/div_dept/train/rad_guide/effects.html

- We assume that any radiation exposure, no matter how small, carries with it some risk.
- However, we know that on average these risks are comparable to or smaller than risks we encounter in other activities or occupations that we consider safe.
- Since we have extensive control over how much radiation exposure we receive on the job, we can control and minimize this risk.
- The best approach is to keep our dose As Low As Reasonably Achievable.
- Minimizing the dose minimizes the risk.

How do I keep my exposure low?

- **Reduce <u>Time</u>** in radiological area
- **Increase <u>Distance</u>** to radioactive materials
- **Use <u>Shielding</u>** between you and sources of radiation

Control of Radiation Exposure

- Protective Measures
  - Time
    - Less time = less exposure
  - Distance
    - Further away = less exposure
  - Shielding
    - Intensity is reduced by absorption and scattering by the material between you and the source

Radiation Emergencies

Types of Radiation Emergencies

Nuclear Emergencies
A nuclear emergency involves the explosion of a nuclear weapon or improvised nuclear device (IND).
The explosion produces an intense pulse of heat, light, air pressure, and radiation.
Nuclear explosions produce fallout (radioactive materials that can be carried long distances by the wind).
Learn more about nuclear emergencies

Nuclear Power Plant Accident
An accident at a nuclear power plant could release radiation over an area.
Nuclear power plants have many safety and security procedures in place and are closely monitored by the Nuclear Regulatory Commission

Dirty Bomb A dirty bomb (also known as a radiological dispersal device) is a mix of explosives such as dynamite, with radioactive powder or pellets.
A dirty bomb cannot create an atomic blast.
When the explosives are set off, the blast carries radioactive material into the surrounding area.

Transportation Accidents
It is very unlikely that a transportation accident involving radiation would result in any radiation-related injuries or illnesses.
Shipments involving significant amounts of radioactive material are required to have documentation, labels, and placards identifying their cargo as radioactive.

Radiological Exposure Device
A radiological exposure device (also called a hidden sealed source) is made of or contains radioactive material.
REDs are hidden from sight to expose people to radiation without their knowledge.

Occupational Accidents
Radiation sources are found in a wide range of settings such as health care facilities, research institutions, and manufacturing operations.
Accidents can occur if the radiation source is used improperly, or if safety controls fail.

Dirty Bombs

- Conventional bomb attached to a source of radioactivity (e.g., Cobalt-60)
- Explosion spreads radioactivity resulting in widespread contamination
- Result in few casualties
- ***Public panic*** is greatest danger
- Economic impact is far reaching when compared to INDs or military weapons

Management of Radiation Exposed/Contaminated Patients

Protecting Staff from Contamination

- Follow universal precautions.
- Survey hands and clothing with a radiation meter.
- Replace contaminated gloves or clothing.
- Keep the work area free of contamination.

Key Points

- Contamination is easy to detect and most of it can be removed.
- It is very unlikely that medical staff will receive large radiation doses from treating contaminated patients.

Reducing Radiation Exposure

Time

Minimize time spent near radiation sources.

Distance

Maintain maximal practical distance from radiation source.

To Limit Caregiver Dose to 5 rem

Distance	Rate	Stay time
1 ft	12.5 R/hr	24 min
2 ft	3.1 R/hr	1.6 hr
5 ft	0.5 R/hr	10 hr
8 ft	0.2 R/hr	25 hr

Shielding

Place radioactive sources in a lead container.

Detecting and Measuring Radiation

- **Instruments**
  - Locate contamination - GM Survey Meter (Geiger counter)
  - Measure exposure rate - Ion Chamber
- **Personal Dosimeters - Measure doses to staff**
  - Radiation Badge - Film/TLD
  - Self-reading dosimeter (analog and digital)

Patient Management - Priorities

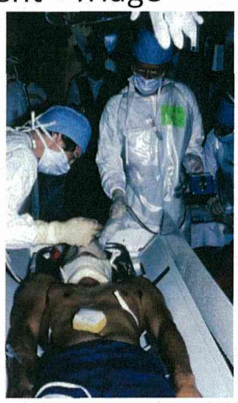
Triage

- Medical triage is the highest priority.
- Radiation exposure and contamination are secondary considerations.
- Degree of decontamination is dictated by number of and capacity to treat other injured patients.

Patient Management - Triage

Triage based on:

- Injuries
- Signs and symptoms - nausea, vomiting, fatigue, diarrhea
- History - Where were you when the incident occurred, i.e. how far from the actual event site?
- Contamination survey



Contamination Surveys

- Survey with GM survey meters.
- Those familiar with the use of radiation detection instruments should operate them.
- Goal is <5 times background.
- Prepare protocol for survey and documentation.

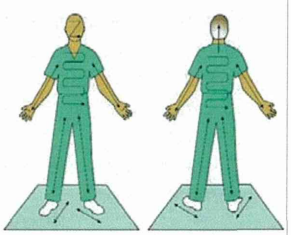


photo credits: REACTS

- Hold probe ~1/2 inch from surface.
- Move at a rate of 1 to 2 inches per second.
- Follow logical pattern.
- Document readings in counts per minute (cpm).

Patient Management - Decontamination

- Carefully remove and bag patient's clothing and personal belongings (typically removes 95 percent of contamination).
- Survey patient and, if practical, collect samples.
- Handle foreign objects with care until proven nonradioactive with survey meter.
- Decontamination priorities:
  - Decontaminate wounds first, then intact skin.
  - Start with highest levels of contamination.
- Change outer gloves frequently to minimize spread of contamination.
- Protect uncontaminated wounds with waterproof dressings.

Patient Management - Decontamination

- Contaminated wounds:
  - Irrigate and gently scrub with surgical sponge.
  - Extend wound debridement for removal of contamination *only* in extreme cases and upon expert advice.
- Avoid overly aggressive decontamination.
- Change dressings frequently.
- Decontaminate intact skin and hair by washing with soap & water.
- Remove stubborn contamination on hair b cutting with scissors or electric clippers.
- Promote sweating.
- Use survey meter to monitor progress of decontamination.

Patient Management - Decontamination

- Cease decontamination of skin and wounds:
  - When the area is less than twice background, or
  - When there is no significant reduction between decon efforts, and
  - Before intact skin becomes abraded.
- Contaminated thermal burns
  - Gently rinse. Washing may increase severity of injury.
  - Additional contamination will be removed when dressings are changed.
- Do not delay surgery or other necessary medical procedures or exams . . . residual contamination can be controlled.

Treatment of Internal Contamination

- Radionuclide-specific
- Most effective when administered early
- May need to act on preliminary information
- NCRP Report No. 65, *Management of Persons Accidentally Contaminated with Radionuclides*

Radionuclide	Treatment	Route
Cesium-137	Prussian blue	Oral
Iodine-125/131	Potassium iodide	Oral
Strontium-90	Aluminum phosphate	Oral
Americium-241/ Plutonium-239/ Cobalt-60	Ca- and Zn-DTPA	IV infusion, nebulizer

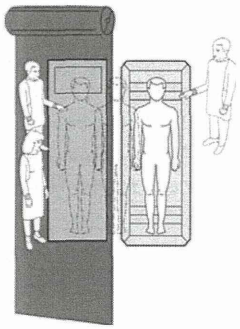
Treatment of Large External Exposures

- Estimating the severity of radiation injury is difficult.
  - Signs and symptoms (N,V,D,F): Rapid onset and greater severity indicate higher doses. Can be psychosomatic.
  - CBC with absolute lymphocyte count
  - Chromosomal analysis of lymphocytes (requires special lab)
- Treat symptomatically. Prevention and management of infection is the primary objective.
  - Hematopoietic growth factors, e.g., GM-CSF, G-CSF (24-48 hours)
  - Irradiated blood products
  - Antibiotics/reverse isolation
  - Electrolytes
- Seek the guidance of experts.
  - Radiation Emergency Assistance Center/Training Site (REAC/TS)
  - Medical Radiobiology Advisory Team (MRAT)

Patient Management - Patient Transfer

Transport injured, contaminated patient into or out of the emergency department:

- Cover clean gurney with two sheets.
- Lift patient onto clean gurney.
- Wrap sheets over patient.
- Roll gurney into emergency department or out of treatment room.



Facility Recovery

- Remove waste from the emergency department and triage area.
- Survey facility for contamination.
- Decontaminate as necessary:
  - Normal cleaning routines (mop, strip waxed floors) typically very effective.
  - Periodically reassess contamination levels.
  - Replace furniture, floor tiles, etc., that cannot be adequately decontaminated.
- Decontamination goal: Less than twice normal background . . . higher levels may be acceptable.

Special Considerations

- High radiation dose and trauma interact synergistically to increase mortality.
- For patients who received doses >100 rad:
  - Close wounds, attend to any infection, look out for infections
  - Wound care, burn care, and surgery should be done in the first 48 hours or delayed for 2 to 3 months

24-48 Hours ~3 Months After adequate hematopoietic recovery

Other Considerations

- Victims may include the terrorist(s) (if this is a dirty bomb situation).
- In most cases, following universal precautions is all that is necessary to protect the staff.
  - Risk to caregivers, who would likely receive low doses, is very small.
  - Hospital staff doses at Chernobyl <1 rem.
  - 10 rem increases the risk of fatal cancer by ~1 percent.
  - 25 rem increases the risk of severe hereditary effects by ~0.1 percent.
- Preplan who will be given radiation dosimeters

Other Considerations

- Larger hospitals or large metropolitan areas should consider stocking decorporation agents.
- Dose rates to first responders 20 cm from patient with uniform surface contamination:
  - Cesium-137, 100 $\mu Ci/cm^2$ – 1 rem/hr
  - Cobalt-60, 100 $\mu Ci/cm^2$ – 3.9 rem/hr
- Dose rates to surgeon standing 20 cm from patient with radioactive fragment (0.2 mm long, 0.2 mm radius, embedded 20 cm deep)
  - Cobalt-60, 1 Ci – 2.5 rem/hr

Psychological Casualties

- Terrorist acts involving toxic agents (especially radiation) are perceived as very threatening.
- Mass-casualty incidents caused by nuclear terrorism will create large numbers of worried people who may not be injured or contaminated.
- Establish a center to provide psychological support to such people.
- Set up a center in the hospital to provide psychological support for staff.

Psychological Casualties

- Affected by fear of radiation and misunderstanding of consequences.
- Long-term psychological effects could arise hours or days after an incident.
- Counsel on acute and potential long-term physical and psychological effects.
- Psychological effects include:

Anxiety disorders Post traumatic stress disorder
Depression Insomnia
Traumatic neurosis Acute stress disorder

Psychological Casualties

- Provide psychological counseling to staff, victims, and their families.
- High-risk groups include emergency workers, children, mothers with small children, cleanup workers.
- Provide exposed patients with a "sense of control of their health."
- Resources:

http://www.madison.va.gov/PTSD
http://www.afrri.usuhs.mil/outreach/pdf/2edmmrchandbook.pdf

Contaminated Corpses

- Disaster Mortuary Operational Response Teams (DMORT)
- Restrict autopsies of highly radioactive corpses.
- No embalming or cremation.
- Health physics assistance for autopsies:
  - Use contamination control.
  - Wear protective clothing.

Key Points

- Medical stabilization is the highest priority.
- Train/drill to ensure competence and confidence.
- Preplan to ensure adequate supplies and survey instruments are available.
- Universal precautions and decontaminating patients minimize exposure and contamination risk for staff.
- Early symptoms and their intensity are an indication of the severity of the radiation injury.
- The first 24 hours are the worst; then you will likely have many additional resources.